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Developing the Maturity Model of Strategic Alliances Using the Weighted Fuzzy Inference System

Saeed Roshandel[1], Mohammad Hossein Karimi Govareshaki[1,*], Morteza Abbasi[1]

[1] Department of Industrial Engineering, Faculty of Management and Industrial Engineering, Malek Ashtar University, Tehran, Iran; roshandel.saeed@mut.ac.ir; mh_karimi@mut.ac.ir; mabbasi@mut.ac.ir.

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Abstract

Maturity models are valuable ways to help manufacturing organizations develop their collaboration. However, there is a lack of empirical work on developing a strategic alliance maturity model with clear guidelines. So, there is no model to measure the maturity of a strategic alliance with an evaluation tool that can deal with the inaccuracy caused by human judgment and the inherent uncertainty of the evaluation. This research created a strategic alliance maturity model based on a weighted Fuzzy Inference System (FIS) through a clear and precise procedure and developed a multi-method approach, including literature review, interviews, focus groups, and case studies, from model design to model evaluation. In this research, to obtain the weight of the model's dimensions, the Fuzzy Data Envelopment Analysis (FDEA) technique has been used, which has suitable capabilities for this purpose. The proposed model has been evaluated and validated through a case study. The results of the present study show that this approach provides a strong and practical diagnostic tool based on a set of strategic alliance maturity indicators. By using the results of this model and analyzing the gaps for the first time, an action plan can be prescribed to increase the maturity level of the strategic alliance.

Keywords: Supply chain management, Strategic alliance, Weighted fuzzy inference system, Maturity model.

1 | Introduction

Strategic partnership is a key and important type of long-term partnership. Conceptually, a strategic partnership is a formal or informal agreement between several economic enterprises to improve performance and competitive position by participating in providing and exploiting partners' resources [1–3].

Corresponding Author: mh_karimi@mut.ac.ir

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Despite the fact that strategic partnership has been used as a business model in industries such as pharmaceuticals, automobiles, air transportation, and electronics more than other industries, its potential capacity in different industries and especially for improving the competitiveness of economic enterprises cannot be overlooked. Regardless of the prominent role of partnerships in improving competitiveness, researchers' findings indicate that strategic partnerships can play an influential role in business survival, especially if these partnerships are formed technologically and take advantage of research and development synergies [2]. In a strategic partnership, participants share each other's shares from a legal point of view, and thus, independence in decisions will be lost to some extent.

Another type of strategic partnership is a strategic alliance, which is an agreement between two or more parties to move towards a set of agreed goals so that the participating parties remain independent. Strategic alliances are a type of cooperation closely related to the type of strategic partnership. The difference between these two types of collaboration is the level of independence of the parties. Considering that in a strategic alliance, the members will not have legal partnerships in each other's shares, the independence of the participants is preserved, and at the same time, the members align their goals with each other through making commitments. Strategic alliances are well established as an appropriate organizational form and an important means of implementing strategies. In many industries, complexity, and uncertainty have increased to such an extent that operating independently is no longer an option. Strategic alliances have the potential to create various benefits for participating firms, such as access to new technologies and complementary skills, economies of scale, and risk reduction [4].

One of the first steps in improving a strategic alliance is measuring the success rate of an alliance. For this reason, an important tool is a maturity model [5]. MMs are practical tools that play a crucial role in evaluating and improving business processes [6]. There is a lack of empirical work on developing maturity models for strategic alliances and a need for more prescriptive and non-descriptive models and clear guidelines to help leaders understand what stages and where Supply Chain Management (SCM) should improve.

Moreover, imprecision and uncertainty are inherent in collaboration evaluation since it is, in some cases, qualitative by nature or even because of a lack of data, and causes the decision-making to be complex. Studies about maturity models generally do not address the inherent imprecision brought by the intangible aspects of the cognitive judgment of managers and decision-makers [7]. These characteristics suggest that fuzzy logic theory [8] may be appropriate, as it addresses imprecision and incorporates the uncertainty of human decision-making behavior [9] when facing challenges related to the real world [10], reducing the gap between theory and reality. Although the Fuzzy Inference System (FIS) has been widely applied to various problems to overcome the intrinsic imprecision in the criteria evaluation, to the best knowledge of the authors of this paper, there is no strategic alliance maturity model with an assessment tool that deals with language imprecision and the ambiguity of human judgment in this area.

This research aims to achieve and develop a new model for measuring the maturity level of strategic alliances, which includes various components. To achieve this goal, the dimensions of the maturity model should be identified first. These dimensions are made up of several criteria. Also, these criteria consist of several indicators, which have been achieved through the combination of content analysis, interviews, focus groups, and case studies. In the next part, the maturity levels of strategic alliances are compiled, and after that, the fuzzy sets related to strategic alliance maturity indicators and maturity levels are designed. Finally, another component that constitutes this research's main goal is designing a Fuzzy Data Envelopment Analysis (FDEA) model to calculate the criteria weights. It is necessary to explain that the DEA is a non-parametric method with various applications in decision-making [11]. Many researchers have recently designed FDEA models to deal with situations where some data have uncertain or ambiguous inputs and outputs [12].

The paper aims to contribute in different ways: 1) it proposes a set of strategic alliance indicators to measure the collaboration status in organizations, 2) it proposes a maturity model to support the transition towards outsourcing to strategic alliance, 3) it uses multiple research methods to support the strategic alliance maturity

model construction and application, combining FISs with indicators, and 4) it pioneers the application of weighted fuzzy rule-based maturity model for evaluating the strategic alliance maturity of organizations in terms of collaboration criteria. Moreover, the proposed approach has several advantages, including: 1) the FIS application facilitates decision-making through approximate reasoning and linguistic terms through fuzzy if-then rules [13], 2) it helps in capturing knowledge-based expert judgments [14], 3) provides an efficient tool to deal with the uncertainty of evaluation processes, and 4) offers a useful and practical solution to understanding, quantifying and handling vague data [15], [16].

The paper is organized into six sections. Section 2 provides the theoretical background, Section 3 describes the methodology, Section 4 presents the model and assessment development, Section 5 focuses on the model application, and the last section (Section 6) offers the paper's conclusions.

2 | Theoretical Background

2.1 | Collaboration and Strategic Alliance

One of the management sciences' most active study fields for a long time has been SCM [17]. The supply chain is one of the most important parts that can differentiate the organization from other competitors in the field of competition and improve its position in the market [18]. The world of SCM is at a pivotal juncture, undergoing a profound transformation in many aspects [19]. One of these aspects is collaboration within a supply chain. Supply chain collaboration is still a challenge due to the predominant low level of maturity in most sectors. The specific literature that could enlighten the context factors and provide empirical data is still inconclusive, leading to a relevant gap to explore [20]. SCM has two sections: internal and external. Linking supply chain functions such as procurement, production, and logistics with demand functions is one of the characteristics of an internal supply chain, and communication between suppliers and buyers who have different principles is one of the characteristics of external supply chains [21]. Cooperation is placed in the second section. Over time, various types of cooperation have been proposed [22], discussed, and used. The most important are networking, coalition, joint venture, outsourcing, strategic partnership, and strategic alliance. Strategic alliances are one of the most recent types of cooperation in the supply chain [23]. The adjective "strategic" is used when one tries to show the importance and long-term of an issue. As a result, strategic alliance is a type of long-term, key, and important collaboration.

A strategic alliance is an agreement between two or more parties to move toward common goals in line with the parties' strategies so that the participating parties remain independent from a legal perspective. A strategic alliance is a type of collaboration whose purpose is synergy [24]. In this type of collaboration, each partner expects that the benefits of the alliance will be more significant than that they could get individually. This alliance often includes technology transfer (access to knowledge and expertise), economic expertise transfer, and cost and risk sharing [25]. This type of collaboration is often a form of horizontal collaboration in which a business contract is concluded between two or more companies that belong to the same level of the supply chain or network [26].

A strategic alliance has three important characteristics: first, participants remain independent after forming the alliance. Secondly, alliances are characteristic of mutual dependence, in which one party is usually vulnerable to the other party. Interdependence leads to joint control and management, complicating alliance management and often creating significant administrative and coordination costs. And third, since partners remain independent, there will be uncertainty about what one side expects from the other. The concept of a strategic alliance is a multidimensional one, and it represents a broad array of strategic partnerships across inter-firm/inter-organizational boundaries with many different alliance types or arrangements ranging from joint ventures, franchising and licensing, business networks, public-private partnerships, vertical supplier-buyer alliances, consortia, and concentric partnerships, among other types [27].

Despite the importance of moving towards strategic alliances, organizations in this category still show little success. Previous research has put failure rates at 50% or more. The high failure rate highlights the difficulties of creating successful alliances and demonstrates the fact that not all organizations are able to maximize the potential value created from their collaboration strategies [28]. As a result, although this type of collaboration has many benefits, using it requires substantial considerations.

2.2 | Strategic Alliance in Supply Chain Management and Performance Improvement

In a brief but comprehensive definition, collaboration is defined as a model in which supply chain members share risks and resources in order to achieve competitive advantage [29].

Most researchers consider the main goal of collaboration to be effective and efficient goals around products, services, information, financial resources, and decisions to provide maximum value for the customer [5]. The advantage of using a cooperation strategy in the supply chain is to improve the organization's performance. This advantage is obtained through reducing costs, increasing revenue generation, increasing the accuracy of forecasts through transparency in exchanging information, improving relationships between supply chain members, improving access to resources, and designing incentive systems [29].

2.3 | The Structure of Maturity Models

In general, the concept of "maturity" is defined as "the state of being complete or ready." Maturity can be evaluated qualitatively or quantitatively and discretely or continuously. Various maturity models have been developed to measure the maturity of a system. The maturity model is described as "stages of quantitative or qualitative capability enhancement to assess its progress concerning defined focus areas" [30].

Maturity models are an established means to support requirements such as assessing the current situation, determining the desired situation, and obtaining possible evolution paths [31]. Maturity models are positioned as a tool to compare the current level of an organization or process to the desired level in terms of maturity, conceptualizing, and measuring [32], being used regularly for benchmarking and continuous improvement [33]. Thus, the concept of maturity can be used for descriptive, prescriptive, and/or comparative purposes [34], [35]. Some of the common properties of maturity models are: 1) levels of maturity, 2) "descriptor" with the name of each level, 3) generic description of each level, 4) dimensions, 5) activities for each dimension, and 6) description of each activity, for each maturity level [16], [35], [36].

Maturity models are usually designed in the form of a matrix; for them, two characteristics, "level" and "dimension" are considered. The "level" characteristic indicates the stages of evolution. Usually, most maturity models have five levels, but the difference between them is the definition they provide for each of these levels. The characteristic of "dimension" refers to the elements, dimensions, or factors that are considered to be assessed for their evolution. These models can be considered tools for evaluating and improving processes, systems, and projects.

2.4 | Maturity Models for Collaboration

One of the most basic maturity models is the Capability Maturity Model Integration (CMMI). This model was first introduced in 2002. The CMMI model deals with three areas: product and service development, service creation, and product and service acquisition. Later editions of this model were also presented in 2006, 2010, and 2018. This model considers five maturity levels: initial, managed, defined, quantitatively managed, and optimized. At the initial level, processes are unpredictable and reactive. Usually, tasks are done later than the scheduled time and at a higher cost than the scheduled budget. At this level, the organizations' tasks are unpredictable, and risks and inefficiency increase. The higher the level of maturity, the more predictable processes, the possibility of carrying out proactive measures increases, the risks are well identified, and the

solutions to face them are considered in advance. Finally, the efficiency and success of the organization's activities will increase. Based on the CMMI model, a group of maturity models has been developed [37]–[39].

Table 1. Comparison of existing models for cooperation maturity.

Model	Year	Dimensions	Level	Scope	Validity
CMMI	2002	Different dimensions for maturity levels	Initial, Managed Defined, quantitatively managed, optimized	Inter-organizational cooperation	Verified
ECMM [40]	2010	project and product management business strategy and process customer management legal environment and level of trust organizational status system and technology innovation	Implemented, managed, standardized, innovative	Collaboration network	Untested
E-CMM [41]	2011	Strategy Process People systems	Delivery, Planning Definition, Management, Culture	Inter-organizational cooperation	Verified
CollabMM [42]	2011	Untransparent	Ad hoc, Planned, Consciously, Reactive	Inter-organizational cooperation	Unverified
IMM [43]	2012	System Information Process	Independent, Ad hoc Coordinated, Domain Unified	Government organizational cooperation	Untested
Boughzala and deVreede [44]	2012	Collaboration features Cooperation management Cooperation process Integration of knowledge and information	Ad hoc Exploring Managing Optimizing	Intra-organizational cooperation	Untested
Boughzala and deVreede [45]	2015	Collaboration features Cooperation management Cooperation process Integration of knowledge and information	Ad hoc Exploring Managing Optimizing	Intra-organizational cooperation	Verified
MM-SCC [38]	2016	Different dimensions for maturity levels	Initial, Managed Defined, Quantified Optimized	Cooperation among supply chain	Verified
Johansen et al. [46]	2017	Different dimensions for maturity levels	Price, Value for money, Development Strategic partner Strategic collaboration	Long-term cooperation in the construction industry	Verified
Schimpf and Christo [39]	2018	Collaborative planning Cooperation strategy Evaluation of cooperation Improving cooperation	Preliminary, Managed Defined, Measured Optimized	Inter-organizational cooperation in the field of research and innovation	Verified
UICMM [37]	2018	Untransparent	Absence, Introductory, Planned, Practiced, Managed, Continuous improvement	Inter-organizational cooperation	Untested
Ho et al. [5]	2020	Different dimensions for maturity levels	Initial Managed Defined Quantified Optimized	Cooperation among supply chain	Verified

2.5 | Application of Fuzzy Logic in Maturity Models

Fuzzy set theory [8] is currently used to develop formalized tools to deal with imprecision intrinsic to a wide variety of problems [47], including the maturity assessment of a company [16], [48]. Fuzzy logic allows a more realistic representation of the real world with simplicity [10]. A FIS is a nonlinear system that applies fuzzy if-then rules to model the qualitative aspects of human knowledge [13], [49].

A FIS is a function that uses human experience (represented as a set of rules) to map a set of inputs to an output. The FIS process mimics human reasoning by interacting a set of linguistic variables with a set of fuzzy rules to produce an output. There are two types of FIS: Mamdani and Sugeno. Of these, Mamdani fuzzy systems can better acquire the knowledge of experts in an intuitive style similar to human thinking [50], [51]. Fuzzy logic is adopted as a more precise solution for constructing a tool that assesses the maturity of an organization, as it allows consideration of all the variables used in the problem [52]. In a fuzzy-based maturity model, fuzzy sets represent ambiguity, uncertainty, and inaccurate information, and the results of qualitative judgments and quantitative data are summarized in a general index [9], [16]. As a result, applying the FIS for the maturity model seems appropriate due to the nonlinear relationships between the inputs and the output of the model.

In order to clarify the difference between this research and previous research, the features, advantages, and disadvantages of other models have been analyzed. This has been done by reviewing the research literature and criticizing past models. Examining the basic maturity models that have been used for cooperation maturity shows that these models are often focused on limited dimensions. For example, the CMMI model, which has been used as the main maturity model in the field of cooperation maturity, is focused on providing a solution to improve the organization's processes. In the CMMI model, the improvement of the process of sharing resources or joint marketing processes is discussed. Still, other dimensions are not considered, such as the improvement of management capabilities, the development of joint technologies, the culture of partnership and cooperation, etc. Based on the identified research gap, the difference between this research and other past research and models will be: 1) the research model, unlike previous research, is specifically designed to measure the maturity of "strategic alliance", 2) in choosing the dimensions of the model of this research, the comprehensiveness of the selected dimensions will be considered in such a way that they include economic, social, organizational, and project management dimensions, components, and indicators, 3) in this research, unlike previous research, the impact of different dimensions in measuring the maturity level of the strategic alliance will be different, and the hierarchical structure of the dimensions of the strategic maturity model will be weighted, and 4) in this research, using mathematical modeling, a quantitative analysis tool will be obtained to identify leverage points that have not been used in any of the past research.

3 | Methodology

This research used conventional methods from previous studies, such as Becker et al. [53] and Caiado et al. [16], to form the maturity model. In this method, four steps are considered. The titles of these four steps are a comparison of existing maturity models, identification of model components, model implementation, and model evaluation. Below is a description of each of these steps.

Step 1. Comparison of existing maturity models.

This step aims to identify the requirements of a maturity model for a strategic alliance and an initial list of criteria dimensions and maturity levels. In this step, a keyword search in the article's title, abstract, and keywords was conducted on the scientific databases. A content analysis stage was applied to the results obtained from this search, and by using an inductive approach for classification, the knowledge obtained from the literature review was collected. At this stage, one of the most important results, descriptions, and analyses was a potential list of model components (levels and dimensions).

Step 2. Identification of model components.

At this stage, by forming a "focus group," sessions were held to design a maturity model and determine a set of critical criteria for a holistic assessment in a systematic way. During these sessions, the existing definition of cooperation maturity levels was examined, and the characteristics of each of these levels were identified. Also, this stage deals with the design of the model's dimensions, which consists of a hierarchical structure of criteria and indicators.

Step 3. Model implementation.

According to the purpose of this research to develop the fuzzy maturity model, the third stage included these activities: creating a research instrument (questionnaire), interviewing and distributing questionnaires to set fuzzy rules, fuzzy operators, and membership functions, and creating fuzzy sets related to input variables and output. To model the perception of experts in decision-making judgments, considering the uncertainty, an expert system composed of FISs with two key elements of fuzzy rules and membership functions was designed. To process the results, the construction of fuzzy inference is done by the Mamdani method, and its adjustment is divided into four steps: fuzzification, evaluation of rules, aggregation of rules, and de-fuzzification [9].

Step 4. Model evaluation.

At this stage, to evaluate the model, a case study was conducted in cooperation between two industries in the field of electronics that produce complementary products. For this issue, an open questionnaire containing several questions has been designed for each indicator presented in the model. After conducting the interviews, the evaluation results were measured based on the indicators of the model. On the other hand, the characteristics of the investigated industry and its current conditions were shared with the expert team, and the expert team members evaluated the maturity level of cooperation. Finally, an analysis of the current and expected maturity level was performed considering the company's recent experience and knowledge of the partner industry, along with its strategic interests in electronics manufacturing. Based on the maturity level of this cooperation, guidelines were also proposed to address the weaknesses of strategic alliances, which are structured in a set of goals aligned with the organization's characteristics. The research stages are based on the method of similar studies, such as Becker et al. [53] and Caiado et al. [16] are shown in *Fig. 1*.

Step	Methods	Main activities	Output
Step 1 Comparison of existing models	Literature review, content analysis	Identification and study of cooperation maturity models, identification of the design requirements of model components, comparison of existing models, development of a list of potential criteria, identification of characteristics of maturity levels	Levels development & dimensions requirements
Step 2 identification of model components	Focus group, CVR	Defining the maturity levels of strategic alliances, categorizing and development of the hierarchical structure of dimensions, criteria and indicators for evaluating the maturity of strategic alliances, selecting effective indicators using the CVR method	Model design
Step 3 Model implementation	Interview, questionnaire, fuzzy logic	Designing, distributing and collecting the questionnaire for building fuzzy sets, analyzing 31 examples of strategic alliances, forming a set of fuzzy rules.	Fuzzy based assessment tool
Step 4 Model Evaluation	Case study	Implementing the research model in a case study, evaluating the characteristics of the maturity level of the case study by the expert team, comparing the results of the model and the expected results	Model application & discussion

Fig. 1. Methodology steps [16], [53].

4 | Model Design

This section presents the model design results. During this section, the construction of the maturity model includes the basic elements (number of levels, definition of each level, number of dimensions, number of criteria, number of indicators, and definition of each). Another important part presented in this section is related to forming a fuzzy assessment tool (FIS).

4.1|Identifying Dimensions, Criteria, and Indicators of Strategic Alliances Maturity Model

As a result, an initial list of dimensions, criteria, and indicators that can be used to evaluate the maturity of a strategic alliance has been formed. This list includes six dimensions, 17 criteria, and 44 indicators. After surveying the experts based on the content validity ratio method described in the previous section, finally, 23 indicators were obtained that reached the minimum value of CVR. This final list is presented in *Fig. 2*.

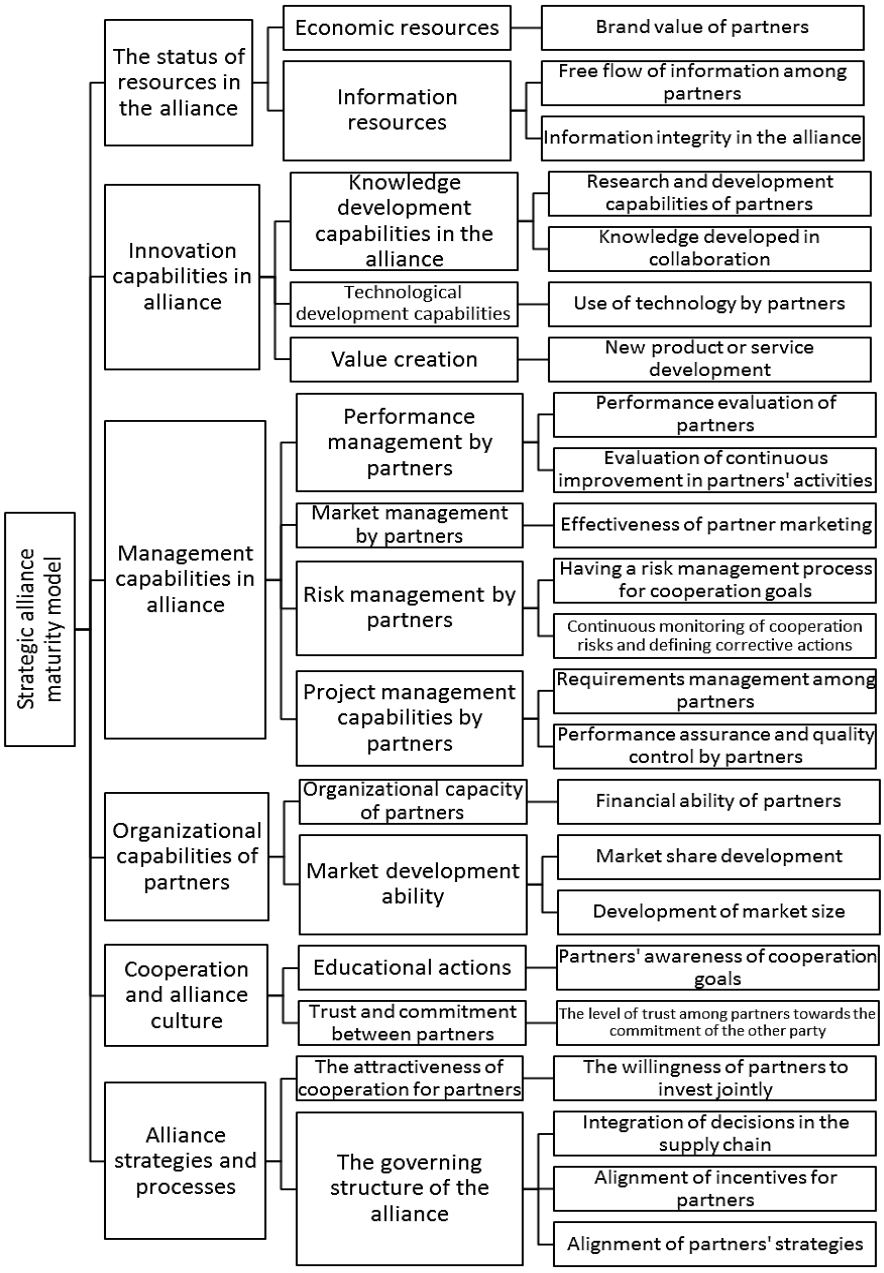


Fig. 2. Hierarchical structure of maturity dimensions, criteria, and indicators.

Based on the literature review and expert interviews, six different aspects should be considered to measure the maturity of strategic alliances. The first aspect to consider is the status of resources in the alliance. The organization's resources include human, informational, financial, equipment, and material resources. Due to the fact that in strategic alliances, the state of attraction, allocation, and sharing of resources is relevant, when measuring the maturity level of the alliance, the above items should be evaluated in cooperation.

In measuring the status of resources in the alliance, the more attraction, allocation, and sharing of resources there are, the higher the level of the strategic alliance will be, with the condition that the independence of the partners is maintained. After checking the content validity ratio on the criteria and indicators under this dimension, two criteria of economic and information resources were accepted as necessary. Under the criteria of economic resources, only the "brand value of the partners" was approved by the experts. Under the criteria of information resources, two indicators of information integrity in the alliance and the free flow of information among partners were confirmed.

The second dimension is the management capabilities of the alliance, which includes the set of management capabilities of partners in cooperation, including project management capabilities, risk management, and performance management. Partners' greater ability to manage different dimensions of collaboration will result in a higher level of strategic alliance. This dimension has four measures of project management capabilities by partners (including performance of quality assurance and control by partners and requirements), risk management by partners (including having a risk management process for cooperation goals, continuous monitoring of cooperation risks, and definition of corrective actions), performance management by partners and market management by partners were recognized.

The third dimension is the organizational capabilities of partners, which represents the set of partners' capabilities from the perspective of organizational capabilities. Greater capabilities such as past cooperation experiences, organization size, and organization financial strength lead to a higher level of strategic alliance. Under this dimension, the criteria of partners' organizational capacity (including partners' financial ability) and market development ability (including market share development and market size development indicators) are included.

The fourth aspect in the maturity model of strategic alliances is the culture of partnership and alliance, which includes two criteria of educational and awareness-raising measures (including partners' awareness of cooperation goals) and trust and commitment between partners (including partners' trust towards the other party's commitment). The higher the level of belief between partners about the importance of the partnership issue, the higher the level of strategic alliance is expected. Factors such as educational and awareness measures and trust and commitment between partners are criteria for measuring the culture of participation and alliance in a collaboration.

Innovation capabilities in the alliance are the fifth dimension of the maturity model of strategic alliances, which has been the focus of researchers in past articles and models. This aspect of strategic alliance, which includes a set of capabilities to develop innovation and technology, is directly related to the level of strategic alliance. In other words, with greater capability of the partners in developing innovation and technology and sharing knowledge, innovation, and technology, a higher level of strategic alliance will be obtained.

The last dimension to consider in a strategic alliance maturity model is alliance strategies and processes. This aspect includes two criteria: the attractiveness of cooperation for partners (including the willingness of partners to invest together) and the governance structure of the alliance (including integration of decisions in the supply chain, the alignment of partners' strategies, and the alignment of incentives for partners), from the management of processes It supports commercial and financial aspects, includes factors that manage the governance structure of the alliance. For example, integration of decisions in the supply chain is one of the subset criteria of this aspect of the model. As much as the integration of decisions in the supply chain is more favorable, the governance structure of the alliance will also be better; as a result, the level of strategic alliance will be higher.

4.2 | Development of Strategic Alliance Maturity Levels

Based on the cooperation maturity models in the literature, it has been concluded that the maturity model levels should have some specific characteristics. First, with the increase in the maturity level of cooperation, the planning of cooperation processes will be developed, and the activities will be more proactive than in the

past. At the low maturity level of collaboration, behaviors are often reactive. Usually, at higher maturity levels, there will be more predictable processes. At low maturity levels, less efficiency is observed in cooperation, and risks have a dominant aspect in the result of processes. At higher maturity levels, it is possible to quantify the results of cooperation processes and properly evaluate and control the status of the process or project. With the increase in the maturity level of the strategic alliance, organizational standards and guidelines are generated in a more structured and complete manner. Another characteristic specific to strategic alliances is that resource sharing increases as the maturity level increases while maintaining the partners' independence. Based on these results, the maturity levels of the strategic alliance are defined in *Table 2*.

The definitions of the maturity levels of the strategic alliance show that the characteristics of "the degree of goals alignment," "the degree of resource sharing," "the predictability of processes," "the ability to quantify and evaluate," and "the degree of access to organizational guidelines and standards" increments with the increase in the maturity level of the strategic alliance, and the characteristics of "level of independence of organizations," "being responsive facing the risks" and "inefficiency in processes or projects" will have a downward trend with the increase in the maturity level of the alliance. The trend of these changes and its comparison among different features is well displayed in *Fig. 3*.

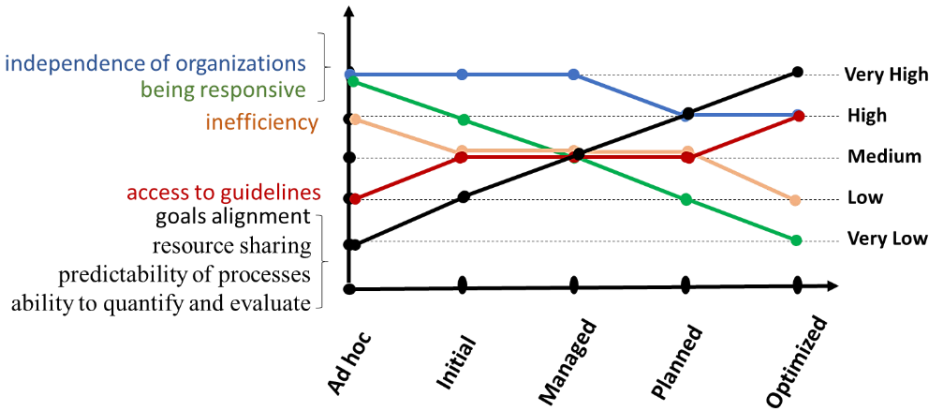


Fig. 3. The trend of changes in the characteristics of each level of maturity levels of strategic alliance.

4.3 | Fuzzy Assessment Tool Development

The basis for the development of FISs is the knowledge obtained from the past [54]. In this research, for this purpose, 31 examples of strategic alliances have been identified, and related data have been collected through the study of past empiricisms, articles, and interviews. These 31 examples are our DMUs. Examples studied include collaborations between HP and Disney, HP and Microsoft, Volkswagen and Suzuki, Cisco and Salesforce, Starbucks and Barnes&Noble, HP, and NTT DoCoMo, Disney and Chevrolet, Red Bull and GoPro, IBM and Schneider Electric, Target and Lilly Pulitzer, T-Mobile and Taco Bell, Louis Vuitton and BMW, Uber and Spotify, Starbucks and Target, Apple Pay and MasterCard, BuzzFeed and Best Friends Animal Society, Google, and Luxottica, Amazon and McAfee, McAfee and Wipro, Snapchat & Square's Snapcash, Infosys and Huawei, Volvo and Dongfeng, Kraft and Starbucks, Ford and Eddie Bauer, Tiffany and Swatch, Lego and Shell and other five samples. These five are the five organizations in Iran. First is Isfahan Electro-Optic Industries' experience collaborating with knowledge-based companies, and four other examples were about companies in the fields of electromechanical activities, telecommunications, and electrical industries.

First, the indicators of the maturity model were measured for each of these 31 samples by holding discussion meetings with experts and completing the questionnaire. Linguistic variables were used to measure these indicators, which resulted in the creation of fuzzy sets. These indicators are the input variables of the FIS that

will be used to measure the output variables (strategic alliance dimensions), as stated in *Fig. 4*. To determine the maturity level of each sample, it is necessary to pay attention to the characteristics of each one of them. These characteristics, which were mentioned in the previous section, can determine the similarity of each sample to different levels of strategic alliance maturity. An expert team has analyzed this section's data and determined the results.

To determine the maturity level of each sample, it is necessary to pay attention to the characteristics of each one of them. These characteristics, which were mentioned in the previous section, can determine the similarity of each sample to different levels of strategic alliance maturity. An expert team analyzed this section's data and determined the results. For this purpose, by surveying experts, the degree of similarity of each sample with the maturity levels of the strategic alliance has been obtained based on the characteristics of each level.

This method represents a fuzzy set in which the relative frequency of each maturity level determines the degree of membership. As a result, fuzzy sets indicating the level of maturity of the strategic alliance based on the experts' opinions have been obtained for studied samples. By de-fuzzifying this set, it is possible to detect the maturity level of strategic alliance for 31 studied samples. For this, the centroid of the fuzzy set should be obtained.

Table 2. Strategic alliance maturity levels.

Maturity Levels		Characteristics
First level	Ad hoc	At this level of strategic alliance, collaborations happen on a case-by-case basis between independent organizations, and in very limited cases, we witness the sharing of resources. Due to the different ways of mentation between management teams of the cooperating organizations, we will see slight alignments of goals. At this level of maturity, process results are rarely predictable, and organizations are entirely passive Against risks and can only react to events. Collaboration processes at this level are deficient in quantification, so it is impossible to evaluate them. At this level, there are no specific guidelines and documented processes. As a result of this prevailing situation, cooperative activities and projects have low efficiency and more failures than successes.
Second level	Initial	The second maturity level of strategic alliances is initial strategic alliances. At this level, collaborations happen in a few cases and follow pre-planned conditions to a small extent. The independence of the organizations is still fully preserved, and only in limited cases we see the sharing of resources. The management teams of partners shared their opinions to some extent; as a result, some of the partners' goals will be aligned. At the initial maturity level, predictability for the processes is very low, and organizations still act passively against risks and can only react to various events. Cooperation processes at this level have little ability to be quantified, and their evaluation is not possible properly. Written instructions for cooperation processes are not in hand. The projects that are proposed during cooperation have average efficiency, and the number of failures and successes are equal.
Third level	Managed	When a strategic alliance reaches this level, organizations' goals in the cooperation category are almost aligned. This is the result of joint thinking of the management teams of partners. Therefore, with prior planning, organizations share a limited part of their resources. At this level, planning and coordination have not been fully implemented because these organizations are completely independent of each other, and decisions are made in separate environments. Due to the fact that part of the actions is pre-planned, the result of the processes can be predicted to an average extent. Therefore, organizations can prepare themselves to some extent in advance for the risks. Another characteristic of this level of maturity is that organizations can model their processes and codify instructions related to this area to a reasonable extent. So, they will have indicators for this part of the process. These indicators increase the possibility of quantifying and evaluating processes. Another feature that can be expressed for this level of cooperation is the increase in the probability of success and efficiency of activities and projects during cooperation compared to previous levels.

Table 2. Continued.

Maturity Levels		Characteristics
Fourth level	Planned	The fourth level of maturity of strategic alliances is planned strategic alliances. At this level, we see that many processes and activities are scheduled in advance during a collaboration. In interaction with each other, the organization's management draws the desired goals of forming a strategic alliance. It makes appropriate planning for sharing the necessary resources (although not all these plans will be implemented). On the other hand, this issue overshadows a part of independence in decisions and makes organizations somewhat dependent on each other. Prior planning for cooperation processes will make these processes predictable to a reasonable extent. This predictability will help organizations adopt a proactive approach to the risks. At this level of maturity, there is a moderate level of access to written guidelines and standards. As a result of all these cases, the probability of ineffective activities and projects being carried out in the cooperation framework is reduced.
Fifth level	Optimized	The most important feature of this level of cooperation is the possibility of sharing resources in line with common goals while maintaining the independence of organizations (at a high level). When a strategic alliance reaches an optimized level, it is possible to see the full consensus of cooperating organizations regarding cooperation goals and the processes of achieving them. For this reason, fully documented guidelines for cooperation processes have been developed and provide the possibility of evaluating and quantifying the results. In terms of predicting the results of the processes and how to face the risks of the cooperation process, suitable information will be available at this level of maturity, and the cooperating organizations will be able to take proactive measures in an entirely favorable way regarding the risks of cooperation.

Considering that the fuzzy evaluation tool in this research is a weighted FIS, it is necessary to determine the relative importance of the evaluation indicators to each other. For this purpose, an FDEA model has been used. In this model, the data obtained from the 31 samples studied in the previous section are used as inputs and outputs of the data envelopment analysis, and the best combination of weights has been obtained. So, the basis for weighting the criteria of the maturity model is the knowledge obtained from the past.

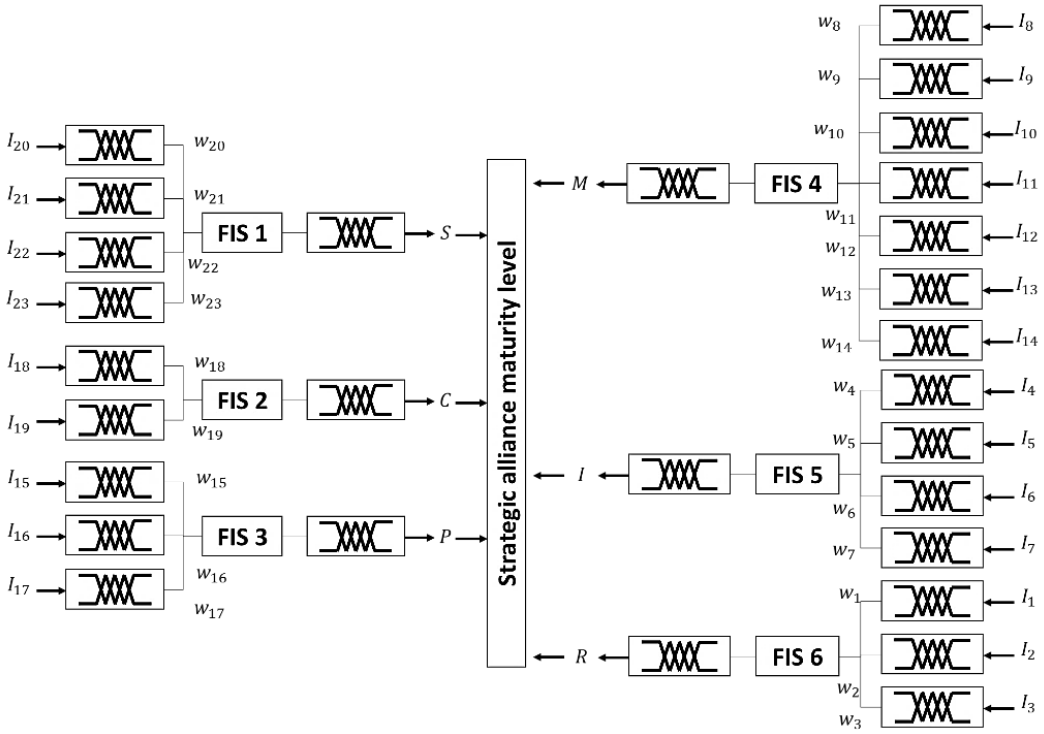


Fig. 4. Fuzzy maturity model structure based on FIS.

4.4 | Maturity Indicators Weighting Using FDEA

Numerous inputs and outputs distinguish the manufacturing activities of the DEA method [55]. The FDEA model in this research has 23 outputs, which are indicators for evaluating the maturity level of strategic alliances. Since the purpose of this model is not to measure efficiency, the model without explicit input has been used. One of the developed DEA methods is solving the problem without dividing the criteria into two categories: input and output. This model is known as enveloping analysis of data without explicit input. In this model, instead of using the term efficiency, the concept of utility is used to rank Decision-Making Units (DMU). In the model of this research, in addition to being fuzzy, the model also lacks input variables. As a result, the model of this research is an FDEA model without explicit inputs (FDEA-WEI). According to these explanations, the proposed model of this research is presented. In the study conducted by Yang [56], a model was presented to obtain the maximum optimal utility of each DMU using a weight vector. The model of this research is designed in such a way that it calculates the utility for all DMUs with one execution. In fact, in this model, the maximum value of the difference with the best utility value for the set of DMUs (min-max) will be minimized. Thus, by obtaining a single weight vector for all DMUs, the best utility value is obtained.

We assume that there are n ($j = 1,2,3, \dots, n$) DMUs for evaluation. Each unit has s outputs. The value of these output criteria for DMU number j is $\tilde{y}_{jr}$ where $r = 1,2,3, \dots, s$ and $\tilde{y}_{jr}$ is a triangular fuzzy number in the form $(y_{jr}^{l}, y_{jr}^{m}, y_{jr}^{u})$. Based on these definitions, the DEA model is rewritten as follows [56], [57]. In this model, $j = 1,2,3, \dots, n$represents the difference between the unit's utility and the maximum utility that can be achieved. L, θ and $\bar{y}_{jr}$ are auxiliary variables for linearization of the model [57], and α represents the value for alpha-cut.

$$\min \theta$$

$$d_j \le \theta, \qquad \text{for all } j. \tag{1}$$

$$\sum_{r=1}^{s} \bar{y}_{jr} + d_j = 1, \qquad \text{for all } j. \tag{2}$$

$$\sum_{r=1}^{s} u_r = L. \tag{3}$$

$$u_r\left(\alpha y_{jr}^{m} + (1-\alpha) y_{jr}^{l}\right) \le \bar{y}_{jr} \le u_r\left(\alpha y_{jr}^{m} + (1-\alpha) y_{jr}^{u}\right), \qquad \text{for all } r, j. \tag{4}$$

$$\alpha + (1-\alpha)1^{l} \le L \le \alpha + (1-\alpha)1^{u}. \tag{5}$$

$$u_r \ge \varepsilon, \text{for all } r. \tag{6}$$

The FDEA without explicit input model (*Eqs. (1)-(6)*) was implemented according to the obtained fuzzy sets. As a result of this model, the best combination of weights in each part of the hierarchical structure was obtained. The result of this section is given in *Table 3*. To obtain the weight of the indicators, it is necessary to pay attention to the fact that these indicators were obtained by asking the opinions of experts using the CVR method, and as a result, the weight of none of them should be equal to zero. For this reason, in *Eq. (6)*, the weight of each indicator is considered greater than ε so that at least one percent of the total weights are assigned to each one.

Table 3. Strategic alliance maturity evaluation indicator's weights.

Dimension Title	Weight	Criteria Title	Weight	Indicator Title (I)	Weight (w)
The status of resources in the alliance (R)	18.4 %	Economic resources	11.1 %	Brand value of partners (I_1)	11.1 %
		Information resources	7.3 %	Free flow of information among partners (I_2)	1 %
				Information integrity in the alliance (I_3)	6.3 %
Innovation capabilities in alliance (I)	20.2 %	Knowledge development capabilities in the alliance	9.1 %	Research and development capabilities of partners (I_4)	5 %
				Knowledge developed in collaboration (I_5)	4.1 %
		Technological development capabilities in the alliance	3.6 %	Use of technology by partners (I_6)	3.6 %
		Value creation	7.5 %	New product or service development (I_7)	7.5 %
Management capabilities in alliance (M)	19.7 %	Performance management by partners	2 %	Performance evaluation of partners (I_8)	1 %
				Evaluation of continuous improvement in partners' activities (I_9)	1 %
		Market management by partners	6.9 %	Effectiveness of partner marketing (I_{10})	6.9 %
		Risk management by partners	6.9 %	Having a risk management process for cooperation goals (I_{11})	5.9 %
				Continuous monitoring of cooperation risks and defining corrective actions (I_{12})	1 %
		Project management capabilities by partners	3.9 %	Requirements management among partners (I_{13})	2.9 %
				Performance assurance and quality control by partners (I_{14})	1 %
Organizational capabilities of partners (P)	10.7 %	Organizational capacity of partners	4.4 %	Financial ability of partners (I_{15})	4.4 %
		Market development ability	6.3 %	Market share development (I_{16})	5.3 %
				Development of market size (I_{17})	1 %
Cooperation and alliance culture (C)	15.7 %	Educational actions	7.7 %	Partners' awareness of cooperation goals (I_{18})	7.7 %
		Trust and commitment between partners	8 %	The level of trust among partners towards the commitment of the other party (I_{19})	8 %
Alliance strategies and processes (S)	15.3 %	The attractiveness of cooperation for partners	1 %	The willingness of partners to invest jointly (I_{20})	1 %
		The governing structure of the alliance	14.3 %	Integration of decisions in the supply chain (I_{21})	1 %
				Alignment of incentives for partners (I_{22})	11 %
				Alignment of partners' strategies (I_{23})	2.3 %

5 | Model Application and Discussion

5.1 | Evaluation of the Model Through a Case Study

In order to evaluate the presented model, the maturity level of the strategic alliance of the case study was measured using two methods. In the first, the information related to the characteristics of a strategic alliance was analyzed by a team of experts, and the current maturity level according to the current experience and knowledge of the company and its partner industry, along with its strategic interests in the production of electronic equipment. This expert team consisted of six experts with extensive knowledge about the company's production processes and strategies, whose characteristics are detailed in *Table 4*.

Table 4. Profile of expert team.

Respondents	Level of Education	Experience	Role	Field
1	Master's degree	Over 10 years	Manager	Planning and management
2	Complete college education	Over 10 years	Manager	Quality
3	Master's degree	Over 10 years	Manager	Commerce
4	Complete college education	5-10 years	Supervisor	Planning and management
5	P.H.D	5-10 years	Supervisor	Production
6	Master's degree	Over 10 years	Manager	Production

Then, the instructions for measuring the level of maturity based on the model presented in this research were given to a team of evaluators so that this team could determine the value of the indicators. With this action, it is expected that the results of both methods will be similar to each other. That is, the expert team uses their knowledge and experience, and the evaluator team uses the model of this research to obtain the same strategic alliance maturity level. In this case, it can be claimed that the model presented in this research has sufficient validity to measure the maturity level of strategic alliances. *Table 5* shows the evaluation results by the expert team.

Table 5. The results of measuring the maturity level of the strategic alliance by the expert team.

Res.	Independence of Organizations	Being Responsive	Inefficiency	Access to Guidelines	Goals Alignment	Resource Sharing	Predictability of Processes	Ability to Quantify and Evaluate
1	Completely independent	In all cases	In half of the times	Rarely found	The goals are not the same	Sometimes, it is done	It rarely happens	No quantitative indicators
2	Completely independent	almost always	Medium	There is, but not enough at all	They are not aligned at all	Human resources only	Only in headquarters processes	Evaluation is possible but difficult
3	Completely independent	In all fields	In many cases	Almost non-existent	It rarely happens	It is never done completely	Outputs cannot be predicted	They rarely happen
4	Completely independent	almost always	In almost 50% of the projects	Medium	Not visible	For advice only	In some processes	It isn't easy to define indicators
5	Completely independent	In all cases	In important projects	No applicable instructions	It is only seen in some cases	It rarely happens	It rarely happens	It's not possible
6	Completely independent	Mostly	Medium	Not available	It rarely happens	It rarely happens	It is not predictable	It is almost impossible
Agg.	Very high	High	Medium	Medium	Low	Low	Low	Low

As it was declared, the expert team, which has perfect knowledge about the company, analyzed the status of its strategic alliance with one of its business partners. The company has had business contracts with its partner for the past 15 years. The products of these two companies are complementary, which means that the end customers should have both companies' products available simultaneously. Also, the companies are almost exclusive in their regional production and do not have numerous and powerful competitors. As a result of

this issue, the final customers have a good reception for these two products simultaneously. This has made the success of the collaboration critical to their commercial success. However, the cooperation of these two companies in the current situation follows the pre-planned conditions to a small extent. This issue has caused the supply of items not to arrive on time and has unsatisfied the final customers.

In this cooperation, the complete independence of these two companies is preserved, and only in limited cases will we witness the sharing of resources. This sharing of resources rarely happens in the field of specialized consulting, but other resources are not shared between companies. The management teams of the cooperating organizations shared their opinions to some extent. As a result of this action, a very small part of the goals of the cooperating organizations will be aligned. Still, this alignment will not happen until the lower organization levels and will be the cause of organizational conflicts. There is little predictability for cooperation processes, and organizations are still passive in the face of risks and can only react to events. The projects that are proposed during cooperation have average efficiency, and the number of failures and successes are equal. Based on these explanations, the result of the expert team's assessment of the strategic alliance is "Initial Level."

After forming a two-member team to evaluate the maturity level using this research model, the evaluation indicators were measured, and the FIS was implemented for the measured values. The output was based on *Table 6* and *Fig. 5*.

Table 6. Strategic alliance maturity evaluation indicators weights.

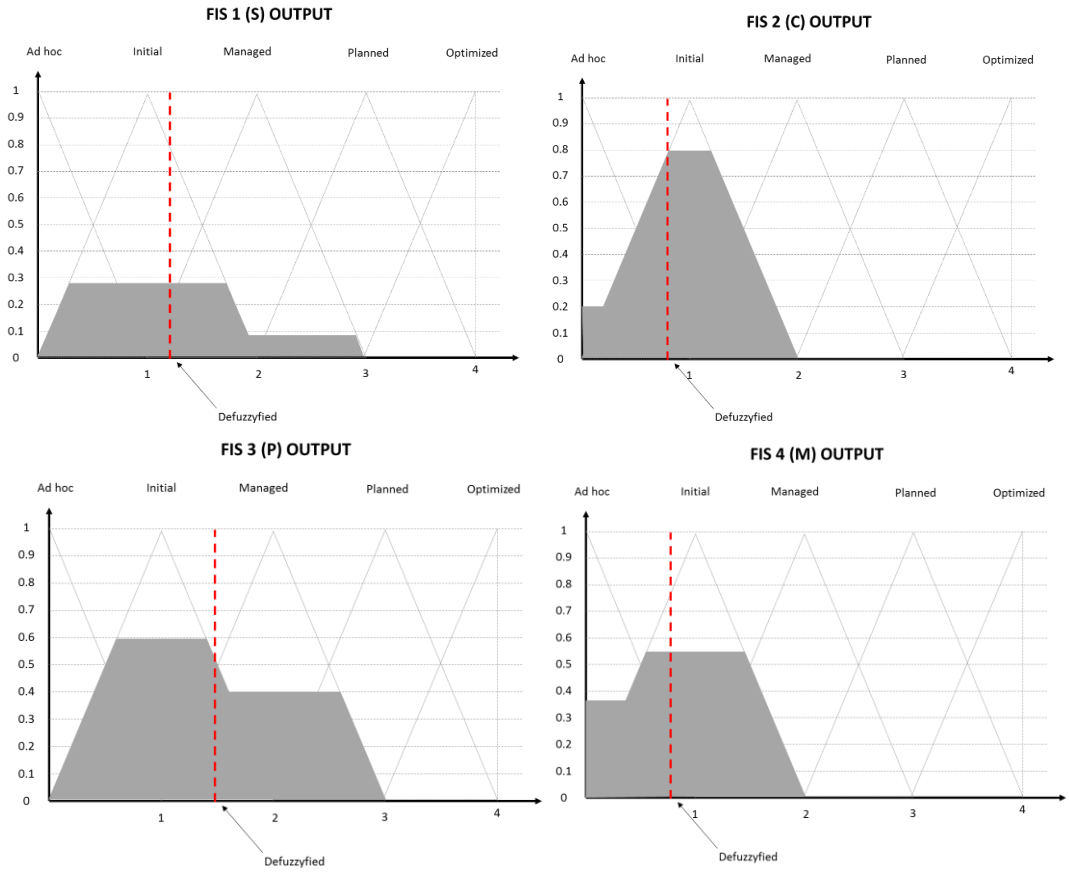
Dimension	Criteria	Indicator	Value (%)
The status of resources in the alliance (R)	Economic resources	Brand value of partners (I_1)	83
	Information resources	Free flow of information among partners (I_2)	30
		Information integrity in the alliance (I_3)	10
Innovation capabilities in alliance (I)	Knowledge development capabilities in the alliance	Research and development capabilities of partners (I_4)	30
		Knowledge developed in collaboration (I_5)	35
	Technological development capabilities in the alliance	Use of technology by partners (I_6)	70
	Value creation	New product or service development (I_7)	40
Management capabilities in alliance (M)	Performance management by partners	Performance evaluation of partners (I_8)	30
		Evaluation of continuous improvement in partners' activities (I_9)	10
	Market management by partners	Effectiveness of partner marketing (I_{10})	25
	Risk management by partners	Having a risk management process for cooperation goals (I_{11})	20
		Continuous monitoring of cooperation risks and defining corrective actions (I_{12})	15
	Project management capabilities by partners	Requirements management among partners (I_{13})	19
		Performance assurance and quality control by partners (I_{14})	33

Table 6. Continued.

Dimension	Criteria	Indicator	Value (%)
Organizational capabilities of partners (P)	Organizational capacity of partners	Financial ability of partners (I_{15})	60
	Market development ability	Market share development (I_{16})	50
		Development of market size (I_{17})	45
Cooperation and alliance culture (C)	Educational actions	Partners' awareness of cooperation goals (I_{18})	20
	Trust and commitment between partners	The level of trust among partners towards the commitment of the other party (I_{19})	30
Alliance strategies and processes (S)	The attractiveness of cooperation for partners	The willingness of partners to invest jointly (I_{20})	26
	The governing structure of the alliance	Integration of decisions in the supply chain (I_{21})	33
		Alignment of incentives for partners (I_{22})	77
		Alignment of partners' strategies (I_{23})	57

By comparing the evaluation with the one done by the expert team, we can see similar results, which shows the validity of this research model.

Figure 5 shows that the cooperation in question has an "Initial" maturity level from the strategic alliance's perspective of all maturity dimensions.



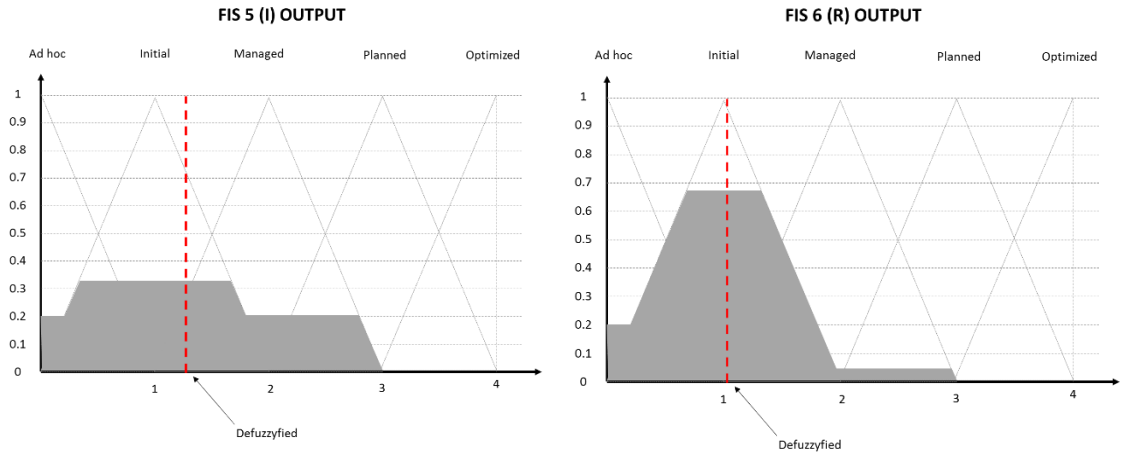


Fig. 5. The result of implementing the weighted fuzzy inference model.

5.2 | Action Plan

Now, on the one hand, with the clarity of the effective dimensions in the formation of a strategic alliance and the importance (weight) of each, and on the other hand, with the knowledge of the values achieved for the development of a strategic alliance, it is possible to check the possibility of increasing the maturity level of the strategic alliance through the evaluation of partners. For this purpose, several guidelines are provided as an action plan:

Guideline 1. Forming a joint technology development committee.

Guideline 2. Establishing quality management systems with identical versions in partner organizations.

Guideline 3. Designing and implementing the external organizational process of managing product requirements and changes.

Guideline 4. Forming a joint management, assessment, and control team for inter-organizational projects.

Guideline 5. Compilation of the strategic document of inter-organizational cooperation.

Guideline 6. Establishment of performance management system in partner organizations.

Guideline 7. Creating an information system to share information related to the capacities and capabilities of partner organizations.

Guideline 8. Creating an information dashboard of contracts to gather information on the latest status of projects.

By applying the proposed set of guidelines, it is expected that the level of strategic alliance of partner companies will be improved, and they will achieve more benefits of strategic alliance.

5.3 | Discussion

This research helps both the academic community and the industrial experts in different ways to be aware of the state of their cooperation from the perspective of forming a strategic alliance, and by solving the existing problems, the possibility of using the benefits of this type of cooperation is provided. In this research, it is important to pay attention to several points. First, a quantitative model based on fuzzy logic is used, which provides the possibility of quantifying qualitative and vague information. This method is a valuable procedure for analysis because the qualitative opinions of decision-makers can be received more accurately and simulate the knowledge of experts. The use of FIS in the literature on maturity models is not new because it overcomes many challenges related to the nature of research in this field. However, to the best of the authors' knowledge, this study is the first one to use fuzzy logic in building a maturity model for a strategic alliance.

Second, the maturity model proposed in this research follows a clear and accurate method based on the steps presented by Becker et al. [53] and Caiado et al. [16], which solves the problem of lack of transparency regarding the construction and application of maturity models. The model development in this method is based on multiple research methods and is validated through a case study. Third, this study presents a real application in a manufacturing organization and its collaboration with a partner company in the field of electronics to show how this approach can be applied in different scenarios. This makes it easier to understand the application of the presented model and provides good documentation of it. Finally, according to the applicability of this model, it can be concluded that the evaluation of the maturity level of a strategic alliance in a real environment has been evaluated by providing an evaluation tool.

6 | Conclusion and Recommendations

This research presents a novel model for assessing the maturity of cooperation specific to strategic alliances for manufacturing companies based on a weighted fuzzy expert system, which can overcome the inaccuracy and uncertainty of previous models. This study focuses on measuring the maturity level of strategic alliances between partner companies.

The current study addresses a research gap by providing a theoretical model based on a precise methodology by providing a maturity model for manufacturing companies participating in strategic alliances. The value of the presented model lies in its combination of scientific rigor, practical relevance, and direct application.

In designing this model, two components are considered: dimensions and levels of maturity. The first dimension is the status of resources in the alliance. In strategic alliances, the state of attraction, allocation, and sharing of resources is relevant; therefore, when measuring the maturity level of the alliance, the above items should be evaluated in cooperation. Another dimension is the management capabilities of the alliance, which includes the set of management capabilities of partners in cooperation, including project management capabilities, risk management, and performance management. The third dimension is the partners' capacities, which represent the set of capabilities of the partners from the perspective of organizational capacities (financial, human resources, development, etc.). The fourth dimension is the culture of partnership and alliance, which includes two measures of educational measures and trust between partners. Innovation capabilities in the alliance are the fifth dimension of the maturity model for strategic alliances, which has also been the focus of past researchers. This important aspect includes partners' capabilities in collaboration to develop innovation and technology. Finally, alliance strategies and processes are considered, which measure the integration of decisions in the supply chain, the alignment of partners' strategies, and the alignment of incentives for partners.

The maturity levels considered in the maturity model express a range of changes in the maturity dimensions of the strategic alliance, each of which has its characteristics. At a low level of maturity, collaborations happen only on a case-by-case basis, and resources are shared in very limited cases. However, with the increase in maturity level, resource sharing increases. As the maturity level of a strategic alliance increases, the processes gain more predictability, and partner organizations change their status from passive to proactive in the face of strategic alliance risks. Another important feature is the failure rate of activities and projects that are proposed during cooperation, which decreases with the increase in the level of strategic alliance.

In this model, using the FIS, the ambiguities in qualitative judgments are resolved and evaluated in a decision-making scenario because fuzzy logic resolves the ambiguity in human judgment. As a result, this article has presented a slightly different model for analyzing the maturity of strategic alliances. This research can also help to determine important directions for research and development by defining a set of guidelines in an action plan that can guide future research.

Like all other research, this research has limitations, the most important of which is the use of an expert team, which limits access to a larger group. Another limitation of this research is the use of data gathered from collaborations in the field of complex products, which may require redefining some of the indicators by

changing the application context of the model. Finally, it is suggested that future researchers provide a strategic expert system to address maturity gaps (between current and expected states) and display the results in a dashboard for agile organization management. Another suggestion for future research is to use alternative methods for developing fuzzy rule sets. Also, researchers can develop fuzzy maturity models for various practical issues in their future studies by following the method of this article.

Author Contribution

Conceptualization, Karimi Govareshki M.H and Abbasi M.; Methodology, Roshandel S., Karimi Govareshki M.H.; Software, Roshandel S.; Validation, Karimi Govareshki M.H; writing-creating the initial design, Roshandel S.; writing-reviewing and editing, Roshandel S., Karimi Govareshki M.H.; project management, Karimi Govareshki M.H. All authors have read and agreed to the published version of the manuscript.

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Data Availability

Almost all practical data to solve the problem are presented in the article. Due to the ethical restrictions, no further data is available.

Conflicts of Interest

Funders played no role in the study's design, in the collection, analysis, or interpretation of the data, in the writing of the manuscript, or in the decision to publish the results.

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